**This contribution is based on chapter 5.5 of the book:** *Pulse-Free Electrical Reflecting Processes; Volume 5, Teaching Library of Radio Locating; German Radar Publishing Company MBH, Published on behalf of: State Secretary Prof. Dr. med. hc Dipl.-Ing. Leo Brandt Düsseldorf; The Ministry of Commerce and Transport of "Nordrheinland_Westfalen", supported* **(presumably financially, AOB)** *this publication.* **Issued in 1957**

## *The automatic seeker "Max-A"* **(Blaupunkt)**

*The number of homing devices designed or under development in Germany was very large [76]. In addition to several ultraviolet methods* **(now usually called infrared or IR, AOB)** *, the development of high-frequency technical* **homing devices** *was started towards the end of the war. If the RF retroreflection method was active, the impulse-free technology was the best option due to the required near resolution ($r_{min}$ <30 m). The following requirements were generally made for the control of the missile [76.77]:*

*Range: at least 1000 m*

*3000 m if possible*

*Detection angle: at least $\pm 10^0$*

*if possible $\pm 30^0$*

*Setting speed: about $30^0$ / sec*

*Setting accuracy: at least $\pm 1^0$*

*Correction voltage: up to $\pm 5^0$ linear with*

*the target tray*

*Time constant: max. 1/20 sec*

*Target deviation: <30 m*

*The target locator "Max" was developed by the company Blaupunkt-Werke GmbH in Berlin (G.Güllner) [76.77], specifically against American round-tracking devices (" Meddo " with λ = 3.1 cm) and as an active device ("Max- A ") against all kinds of destinations [78]. These seekers were intended for the following missiles [59, 79]:*

*Fla rocket "waterfall" for launching from the ground (v ≈ 300 m / s)*

*Fighter missile Hs298 for launching from the aircraft (v ≈ 250 m / s)*

*A wavelength of λ = 3.9 cm (f = 7700 MHz) was intended for the "Max-A" device.*

*In extensive theoretical and experimental preliminary investigations, the question of the optimal antenna arrangements and wavelengths was clarified with regard to the demands made. For the direction-dependent DF antennas, the choice fell on dielectric directional steel according to Mallach [80, 81] ("stem eye"). This was supported in particular by the fact that in this antenna form the bundling is achieved by an axial extension and not by large cross-sectional dimensions ("effective areas"), which would have been difficult to accommodate on board a missile, in particular for aerodynamic reasons. With regard to the choice of wavelength products, numerous points of view have to be weighed up against one another: antenna dimensions (proportional to the λ), range (inversely proportional to the half-width of the antennas),*

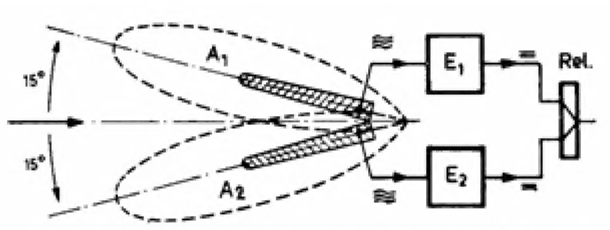



*Bild 133: Energievergleichspeiler mit 2 dielektrischen Stielstrahlern $A_1$ und $A_2$*

*Figure 133: Energy comparator with 2 dielectric spotlights $A_1$ and $A_2$.*

*The directional determination of the reflected target was carried out with the help of the stem emitters according to the principle of "energy comparison bearing" according to the diagram in Figure 133. For each control direction (height or side) a pair of antennas $A_1$ and $A_2$ was required. The two antennas of a pair each had a full width at half maximum of ± $15^0$ . An optimal "squint angle" of the antenna of ± $15^0$ against the optical axis was derived from the contradicting requirements regarding the detection angle (at least ± $10^0$ ) and preliminary examinations . If the reflection in the direction of the optical axis on the two antennas $A_1$ and $A_2$ Arrived (ie in the direction of the arrow on the bisector between the two antenna axes), the two receivers $E_1$ and $E_2$ had the same input voltages, so that the output direct* currents *supplied by the receivers in the relay* Rel canceled *each other out. When the target is deflected in one direction or the other, the received voltages supplied by the antennas no longer matched, so that the response from* Rel*corresponding tax movements have been initiated. In order to reduce the effort, however, in deviation from the schematic illustration in Figure 133, only one receiver for altitude and lateral direction finding was provided, whereby synchronous switchover provided simultaneous high-frequency switching of the four antennas and a switchover of the control relay at the output of the receiver (" Boresighting ").*

*In addition to the four receiving antennas (two each for altitude and lateral bearing), a directional antenna was required for the transmitter. After long tests, a horn was provided as the* transmitting antenna *, which was arranged between the four dielectric stem radiators for reception. The decoupling between the transmitting*

*and receiving antennas was approximately -50 dB (kse ≈ $3 \cdot 10^{-3}$ ). The function of the "Max-A" seeker can be seen in Figure 134.*

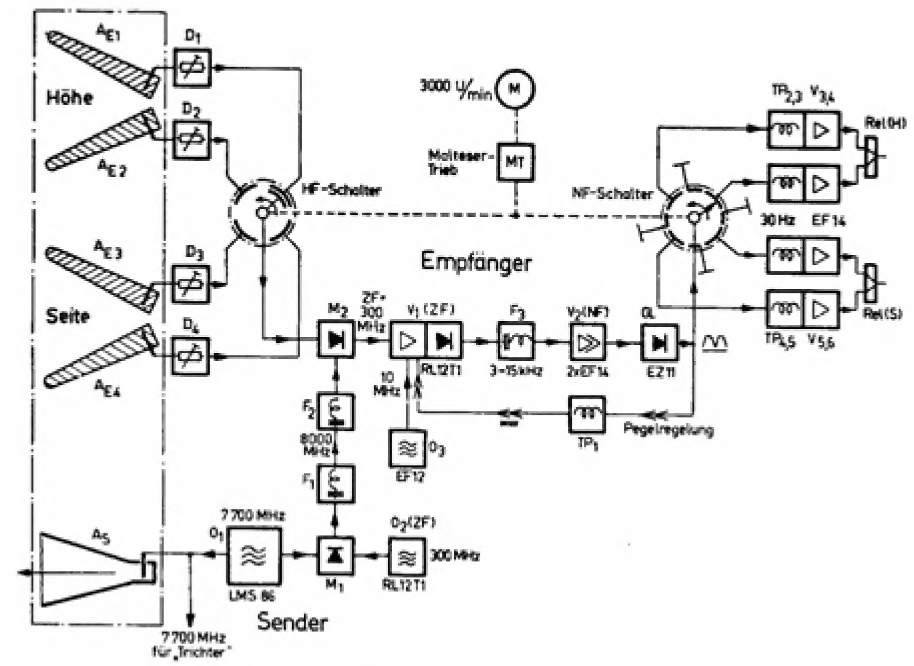



Bild 134: Blockschaltbild des Zielsuchgerätes „Max-A"

*Figure 134: Block diagram of the "Max-A" target seeker*

*The oscillator $O_1$ of the* **transmitter** *consisted of an eight-slot magnetron type LMS86, which was operated with an anode voltage of approximately 500 V. The magnetron was able to deliver a useful output of 5 W at a frequency of 7700 MHz (the maximum operating time of a seeker is only about 1 minute!). The magnetic field of 1600 Gauss was externally excited* **(thus, by means of an electromagnet, AOB)** *and could also only be operated for a short time due to the strong overload. The output power of the oscillator $O_1$ was in addition to the horn $A_s$ of the transmitter (and to the distance igniter "funnel" described in 5.6 to a small extent in the mixing head $M_1$(coupled with germanium crystal diode). The oscillator frequency required by the receiver to be shifted by the intermediate frequency (IF = 300 MHz) compared to the transmitter frequency (8000 MHz) was generated, corresponding to the procedure explained in 1.635 and with Figure 25 ("synchronization control" of transmitter and receiver using a frequency converter "). For this purpose, the transmitter frequency in $M_1$ was modulated with the IF generated by the oscillator $O_2$ (with RL12T1 in a three-point circuit) and then the upper sideband (7700 MHz + 300 MHz = 8000 MHz ) using the two cavity resonators $F_1$ and $F_2$ connected in series ) sifted out. In this way, only one magnetron (in $O_1$) whose frequency fluctuations did not appear in the intermediate frequency of the receiver. The IF bandwidth of the receiver was then based only on the frequency constancy of the oscillator $O_2$ and could be dimensioned accordingly narrow.*

*The retroreflection modulated with the Doppler frequency came from the four receiving antennas $A_{E1}$ to $A_{E4}$ via the "HF switch" on the receiver> The circulating frequency of the switch was n = 3000 rpm (= 50 Hz). The development of this switch was a particularly difficult problem because switch designs using galvanic contacts have not proven themselves. Finally, a solution was found in the form of a capacitive scanning of the voltages supplied by the four antennas with the aid of a rotating capacitor electrode. A smoothly rotating movement of the switch did not work because it produced a disturbing amplitude modulation with the rotation frequency and its harmonics. The HF switch therefore had to be moved in discontinuous steps using a Maltese cross mechanism. The adapters $D_1$ to $D_4$ in the antenna feed lines were used to match the amplitudes delivered by the antennas in pairs and to eliminate adaptation errors due to the HF switch.*

*The receiver started with the mixer $M_2$ in the entrance (with germanium crystal). The intermediate frequency of IF = 300 MHz was fed to the IF amplifier $V_1$. With the help of the pendulum feedback [105, 106, 107], a very high gain in the IF section with subsequent demodulation was achieved with only one tube (RL12T1) in a three-point circuit. The oscillation frequency of $f_p$ = 10 MHz generated by the oscillator $O_3$ (EF12) was coupled into the cathode circuit of the IF tube. The sensitivity of the amplifier was about 100 $KT_0$, the IF amplifier had a half width of ± 0.6 MHz. A Doppler frequency of $f_D$ appeared at the output of the IF section= 3 to 15 kHz (according to equation (79) in 1,631), which was amplified after screening in filter $F_3$ in NF amplifier $V_2$ (2 x EF14) and via a power transformer (ü = 4: 1) to the rectifier Gl (EZ11) came. This was dimensioned so that the charging constant determined by the internal resistance of the rectifier circuit was as small as possible (approx. 1/500 sec).*

*The rectifier Gl first supplied a control voltage to the control grid of the pendulum amplifier tube RL12T1 ($V_1$), which compensated for amplitude fluctuations during the approach to the target. With the help of a low-pass filter $TP_1$, the control loop was given a sufficiently large time constant to avoid being influenced by the switching frequency of 50 Hz.*

*In order to evaluate the retroreflection dependent on the target position, the compensation voltage of the receiver supplied by Gl was led to the peripheral contact of the "NF switch". With the help of a mechanical coupling, the latter moved synchronously with the HF switch and led the control voltages of the receiver via the low-pass filters $TP_2$ to $TP_5$ to the control amplifiers $V_3$ to $V_6$ (each with EF14). The low-pass filters were dimensioned so that the control did not respond to the switching frequency of 50 Hz, but on the other hand reacted as quickly as possible to changes in the target position (time constant about 1/30 sec). Intermediate segments on the LF switch ensured that the output of the receiver was short-circuited during the transition from one to the next switching phase, as a result of which the controls could not be influenced by switching surges. In the anode circuits of each pair of amplifiers, the windings of a high-resistance*

*differential relay were switched on (approx. 3000 Ω per winding), which caused course control on the basis of the height or lateral offset of the target.*

*The installation of the Max-A in the missile was based on aspects that resulted from the respective conditions during deployment (type of launch, angle of attack, most favorable trajectory). Two antenna heads were provided:*

1. *Antenna head for fixed installation, so that the electrical axis was identical to the longitudinal axis of the missile. This head was intended for control according to the "chase course", which was to be used for the use of aircraft to aircraft (eg Jäger rocket Hs298). The range of fire was of the order of 1000 m.*

2. *Movable antenna head for a shot after the "collision course" when using ground (anti-aircraft missiles). The firing range was then much larger than 1000 m.*

*In the collision course according to 2., the missile should first be controlled with radio measuring devices [58, 59] in the vicinity of the target until the detection range of about 1000 m was reached. When the target-searching head detects the target, the antenna head automatically automatically turned in the first stage without the body having to be readjusted. Only when the target was approached more closely, after a certain angle between the missile axis and the target direction was present, did the control of the missile begin (by means of a relay switchover). The antenna head therefore had two course control motors, one of which drove the antenna plate in one direction directly via gear wheels, while the other motor worked in the direction perpendicular to it via a flexible shaft. Here potentiometers were turned, which disturbed a bridge balance and thus caused the control of the missile. The development of the "Max-A" was so far advanced that a fully functional test pattern was available with which tests could be carried out on the ground. A fan was used as a "replacement target", by means of which the Doppler vibrations were simulated at high relative speeds. The calculation resulted in N = 5 W, receiver sensitivity = 100 KT by which the Doppler vibrations were reproduced at high relative speeds. The calculation resulted in N = 5 W, receiver sensitivity = 100 KT by which the Doppler vibrations were reproduced at high relative speeds. The calculation resulted in N = 5 W, receiver sensitivity = 100 $KT_0$, target area $F_{Refl}$ = 1 $m^2$, a range of $r_{max}$ ≈ 2000 m, which could be confirmed by the measurements with the alternative target.*

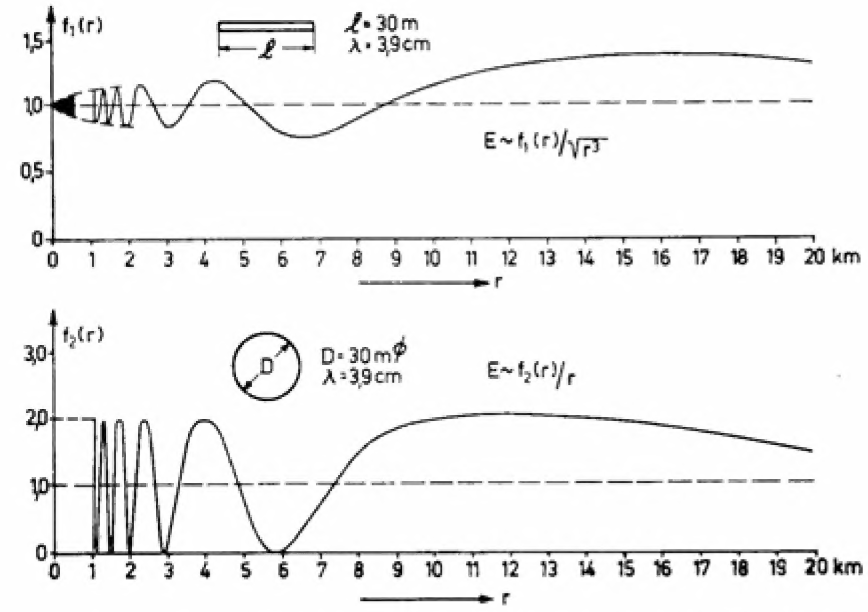



*Bild 135:* Zum Abstandsgesetz der rückgestrahlten Feldstärke bei einem Linear-Reflektor der Länge $l$ = 30 m nach Gleichung (157) (oben) und bei einer Kreisscheibe von $D$ = 30 m Ø nach Gleichung (158) (unten). Wellenlänge $\lambda$ = 3,9 cm

*Fig. 135: For the law of distance of the retroreflected field strength with a linear reflector of length l = 30 m according to equation (157) (above) and with a circular disc D = 30 m according to equation (158) (below). Wavelength λ = 3.9 cm*

*A fundamental difficulty of the method was to be expected in that the distance law for the retroreflective field strength at flight targets of finite extent is not in a monotonous curve of defined form [16]. The result of theoretical investigations in this direction [78] is shown in Figure 135: in the case of a linear, long reflector ($l \gg \lambda$), the reflection of which is in the form of cylindrical waves, the retroreflected field strength is according to the relationship (104) in 1.923 proportional $1 / \sqrt{r^3}$. Taking into account the Fresnel interference due to the finite length of the reflector (e.g. l = 30 m), however, as the upper curve in Figure 135 shows, there is a complicated law of distance of the form:*

$$E_{Refl} = \frac{f_1(r)}{\sqrt{r^3}} \cdot C_1. \tag{157}$$

*The function $f_1$ (r) is superimposed on the monotonous distance law . The conditions when reflecting a circular disk of finite extent (d = 30 m) according to the lower curve in Figure 135 are even more unfavorable:*

$$E_{Refl} = \frac{f_2(r)}{r} \cdot C_2. \tag{158}$$

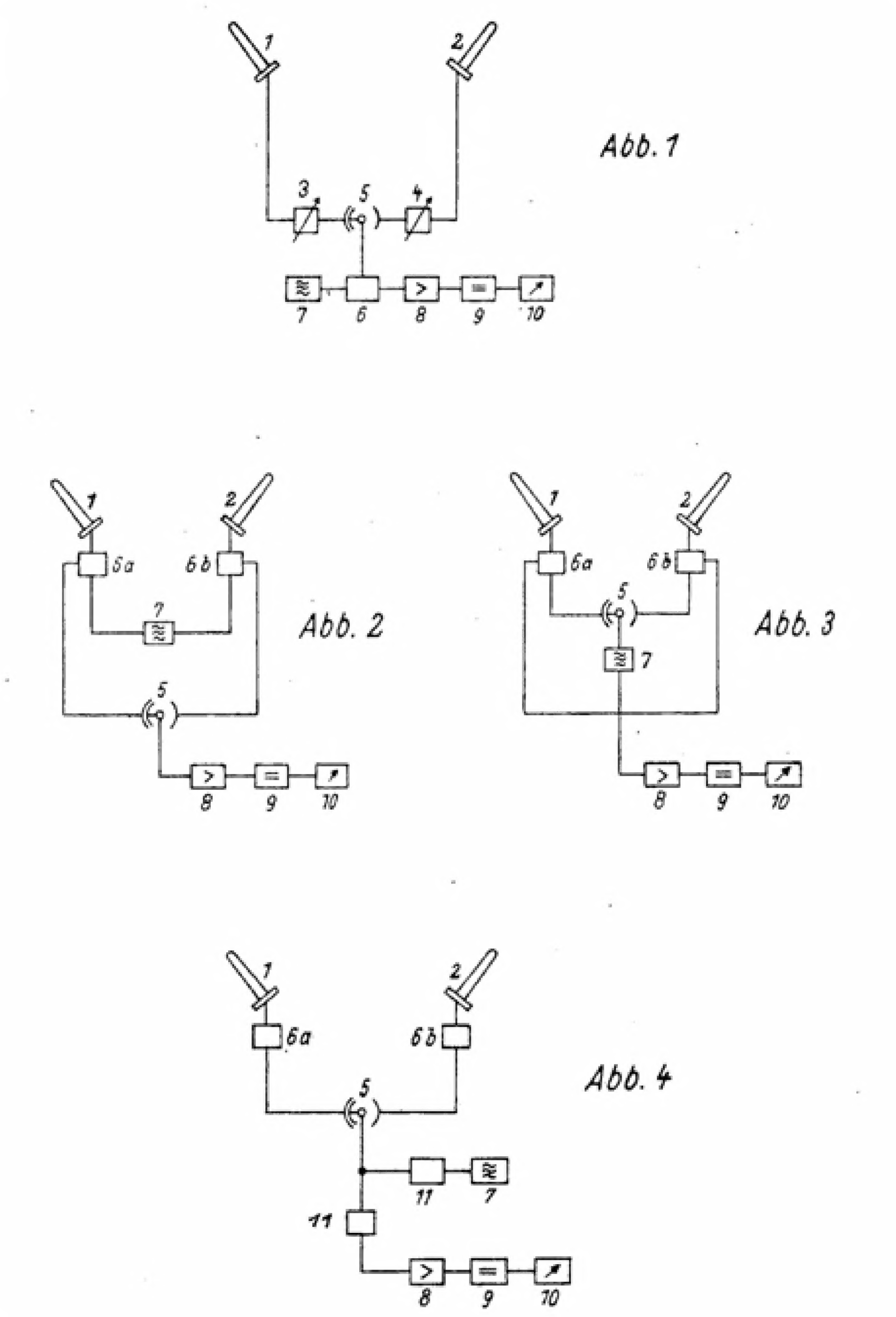
*A "beat" $f_2$ (r) is superimposed on the 1 / r law of specular reflection (according to the relationship (105) in 1.923) (see also in 1.341). This results in doubled amplitudes ($f_2$ = 2) at the distances r = 11.54 km / ( 2 n - 1 ) and in particular zeros ($f_2$ = 0) at the distances r = 5.77 km / n. It is therefore possible that the fluctuations in the field strength cause instability in the course control, or that the missile may even completely lose sight of the target. Given the irregular shape of practical flight destinations, less unfavorable conditions can probably be expected. However, flight tests with the Max-A against flight destinations could no longer be carried out.*

*Max-A and Max-P are both based on German patent* [DE864571](DE864571) *, on behalf of Blaupunkt-Elektronik GmbH, Berlin-Wilmersdorf. Inventors: Dr. Georg Güllner, Darmstadt-Eberstadt; Dr. Johannes Graupner, Darmstadt.* **(both address are post war, AOB)**

*Which claimed:*

*Field strength comparison DF arrangement for short waves*

*Patented December 22, 1944*




**This drawing is self-explaining, and does not need further explanation. The principles of the dielectric antennae, is explained in my [Naxos direction-finder paper](Naxos direction-finder paper) .**

**Both inventors, Güllner and Graubner, were also regular attendees of the [1943/44 AGR sessions](1943/44 AGR sessions) .**

**References:**

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**Equation (79)**

$$f_D = f_{Schw} = \frac{2 v_r}{\lambda} . \qquad (79)$$

Equation (104)

$$N \sim \frac{1}{r^3} \quad \text{oder} \quad E \sim \frac{1}{\sqrt{r^3}}\,. \tag{104}$$

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